ARPA Network Information Center
Stanford Research Institute
Menlo Park, Calif. 94025

NIC #13656
Packet Radio Temporary Note 13

L. V. Griffee (Collins
18 January 1973

# ANTENNA CONSIDERATIONS FOR PACKET RADIO COMMUNICATIONS

The objective of this note is to outline omnidirectional antenna concepts and considerations with emphasis on those best suited to the hand-held terminals. The treatment is given from an antenna point of view and conclusion drawn herein may be obviated when the antennas are included as part of a complete link performance model. Issues such as bandwidth, tuning and matching are not addressed in this first note on the subject of antennas. The antenna concepts considered are restricted to "single antenna" adaptations as opposed to a grouping of directional antennas so arranged as to provide sectoral omnidirectional coverage with multiple inputs. In the event that such groupings appear attractive in the future for use with repeater and/or station level terminals, another note will be written on this subject.

## GENERAL

Implementation of the packet communications system will require the use of several types of antennas, however, the difference in technology represented by the change from conventional communications to packet communications does not create any new demands on the antenna design not previously encountered. The basic parameters to be analyzed for the various terminals that make up the complete system are, 1) directivity, or area of radiation covered by each specific antenna, 2) polarization of the radiated signal, 3) efficiency of the antenna, 4) frequency and 5) the size of the antenna which is primarily a function of the other four parameters. The proper choice of these parameters is a major factor in effectively and efficiently completing the path that links the source of a message with its final destination.

### Hand-Held Units

In order to be practical, the antenna for the hand-held personal terminal must be small and simple. Since the size of an efficient antenna is

Digitized by the Internet Archive
in 2025 with funding from
Amateur Radio Digital Communications, Grant 151

https://archive.org/details/temporary-note-013

largely a function of frequency, the higher frequencies are desirable, however, an antenna can be designed such that the lowest frequencies considered here do not require an objectionably large antenna. The simplest and most common type now in use on most hand-held transceivers is the quarter-wave or near quarter-wave monopole shown in Figure 1. At 300 MHz this is a 10-inch whip or at 3000 MHz a 1-inch post mounted on top of the transceiver. Under ideal conditions the radiation pattern is omnidirectional with maximum signal at an elevation angle of 20 to 40 degrees above the horizon and a null directly overhead. The polarization is vertical. Under these ideal conditions these radiation pattern characteristics are also ideal, however, when in actual use these conditions do not always exist. At 300 MHz the position of the radio with respect to the operator will affect the antenna impedance, its efficiency, and its radiation pattern.

As the frequency is increased the impedance and efficiency are less dependent on operator proximity. Also, the radiation pattern in the near field becomes more stable, but at the same time the reflections from nearby objects, including the operator's body, are more pronounced and partial fading of the signal results from the cancellation effect when the direct and reflected signal arrives out of phase. An example of this is seen in the portable UHF television receiver. Reception can vary from perfect to unsatisfactory by simply moving its location two or three feet with respect to nearby reflecting objects. Overcoming this multipath effect is one of the most difficult problems associated with the hand-held personal terminal.

The antenna radiation characteristics can be made less dependent on operator proximity at the lower frequencies by using a balanced antenna such as a dipole, as shown in Figure 2, rather than a monopole and choking off the R.F. current that ordinarily flows down and is radiated from the radio housing. This increases the size of the antenna and complicates its design, but would improve the signal level significantly at 300 MHz. The crossover point above which a dipole would no longer provide improved operation over a monopole is the frequency at which the top of the transceiver becomes approximately one-half wavelength across its surface. This would probably occur somewhere near 1500 to 2000 MHz.

With antennas it is necessary to consider the nature of the polarization of the signal they receive or radiate. This R.F. polarization, which is a measurement or indication of the direction of the electrical field vector, can be linear, elliptical, or circular. A pictorial representation of this is shown in Figures 3a, 3b, and 3c. Linear polarization can be oriented in any direction such as vertical, horizontal or diagonal and circular can have either a right or left hand sense of rotation. Vertically polarized antenna will receive either a vertically polarized field or a circularly polarized field however a 50 percent power reduction or loss results if the antenna is linear and the field is circular. Likewise, the horizontal antenna will receive either horizontal or circularly polarized energy with a 3 dB loss for circular. A right-hand circularly polarized antenna will theoretically receive no signal from a left-hand field provided both the antenna and the field are purely circular.

One of the major problems associated with portable hand-held antenna is multipath fading causing a strong reflected signal arriving at the antenna 180 degrees out of phase with the direct signal. For linear polarization this can cause almost complete cancellation of the direct signal, however, with circular polarization the reflected signal is of the reverse sense and the cancellation is less severe.

The polarization of both the monopole and the dipole is linear and in order to radiate omnidirectionally, both must be vertically oriented. Since this is the most normal attitude for a hand-held transceiver, maintaining vertical polarization should present no problem, although the merits of horizontal and circular polarization should be examined. Horizontal polarization that is omnidirectional can be obtained through the use of a horizontally oriented tridipole antenna shown in Figure 4. If horizontal polarization had any operational advantages over the vertical, it would be considered, however, it has no advantage and will not be further considered.

Circular polarization, however, will have three limited advantages. It will not have the overhead null that is characteristic of the monopole or dipole. Also the requirement for maintaining vertical orientation of the transceiver will not be as critical. The third and most significant advantage is the phenomonon mentioned previously whereby the signals

bouncing off reflective surfaces tend to be of the opposite sense or circular polarization thus minimizing the fading due to multipath cancellation. It was primarily for this reason that circular polarization was chosen for UHF Satellite communication. The improvement is in the order of 6 to 10 dB.

The only disadvantage of circular polarization is that it complicates the design of the antenna. This is true for the other antennas in the system as well as the hand-held units since all antennas in the system should have the same type polarization.

There are several antenna configurations that can be used for obtaining omnidirectional circular polarization such as 1) the conical spiral, 2) four diagonal dipoles, or 3) the slot excited biconical horn as shown in Figures 5, 6 and 7. Of these the conical spiral is probably the least expensive. The diameter of the base of the conical spiral is approximately 1/2 wavelength at the lowest usable frequency, therefore this antenna could be considered impractical for frequencies below 1500 MHz. The base diameter for this frequency would be 4 inches. It is difficult to envision an antenna of larger dimensions as being practical for a hand-held radio.

It is then concluded that a vertical monopole or possibly a center fed dipole is best suited for the hand-held unit if the frequency chosen is below 1500 MHz. A circular polarized antenna could provide at least 6 dB improvement in circuit margin and would be practical above 1500 MHz. For this reason and also because the size of the antenna changes linearly and inversly with frequency, the higher frequencies are more desirable. However, this reaches a point of diminishing returns if carried too far in that extremely small antennas are also difficult to build. If a frequency were to be chosen at this time which would seem to be most satisfactory from the standpoint of antenna design, it would be between 2500 MHz and 3500 MHz, and the antenna would be a circularly polarized truncated conical spiral mounted on top of the transceivers.

Antennas for Repeater Stations

Many of the problems associated with the hand-held units such as the proximity effect of the operator, tilting of the antenna, and size limitations are not applicable to the repeater station antennas. Since the antenna is fixed, higher gain, in the form of directivity is more practical as well as desirable. Two types of antennas are required for these stations. One type is needed to provide communications with the individual portable personal transceivers. The other is needed to communicate with the central control station. The antenna that is used for receiving and transmitting to the portable units must have a radiation pattern that is omnidirectional in the azimuth plane with gain accomplished by reducing the vertical plane beamwidth.

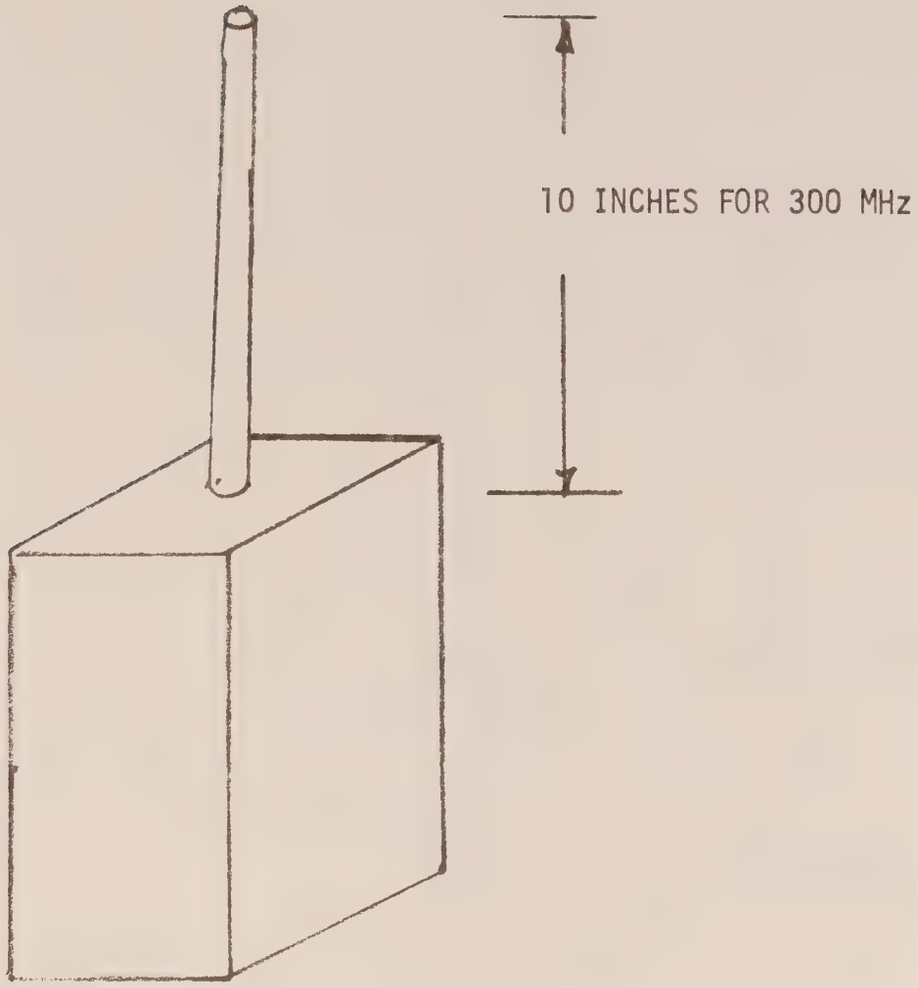
Since the antenna that is used to transmit to and receive from the portable units must have broad azimuth coverage, somewhere between 180 and 360 degrees, a gain of 8 to 10 dB is considered practical. A vertically stacked array of four radiating elements will provide this amount of gain. To achieve 3 dB more gain theoretically requires twice as many radiating elements, however, the added complexity of the antenna feed system increases the losses and a gain in the order of only 2 dB in all that is actually achieved. A four-element array will have a vertical plane beamwidth of approximately 20 degrees.

What has been said for the hand-held units regarding size polarization and cost is also true for the fixed site omnidirectional antennas. For the lower frequencies collinearly stacked, vertically polarized dipoles are practical. At 300 MHz one dipole is 20 inches long and a four element array with optimum spacing between elements is 100 inches long. At the lower UHF frequencies circular polarization can be obtained with diagonal or inclined dipoles as shown in Figure 6. At higher frequencies this technique becomes less practical. At 3 GHz an array consisting of slots on a vertical cylinder are more appropriate and easier to manufacture.

The repeater station antenna that is used to transmit to and receive information from the central station is not limited to 8 or 10 dB gain

The repeater station antenna that is used to transmit to and receive information from the central station is not limited to 8 or 10 dB gain since it is not required to have broad azimuth coverage. A gain of 29 dB can be obtained at 3 GHz with a four-foot diameter parabolic reflector type antenna. A two-foot diameter reflector will have 23 dB gain at the same frequency. The reflector type antenna is probably the most practical for this application at frequencies below 3 GHz. Above 3 GHz a horn may be less expensive.

The polarization for this antenna is not as important as it is for the hand-held units since reflections and multipath do not present a serious problem. For reasons of simplicity, linear polarization is more appropriate.




POLARIZATION: VERTICAL

PATTERN: OMNIDIRECTIONAL WITH NULL OVERHEAD

FIGURE 1. QUARTER-WAVE MONOPOLE

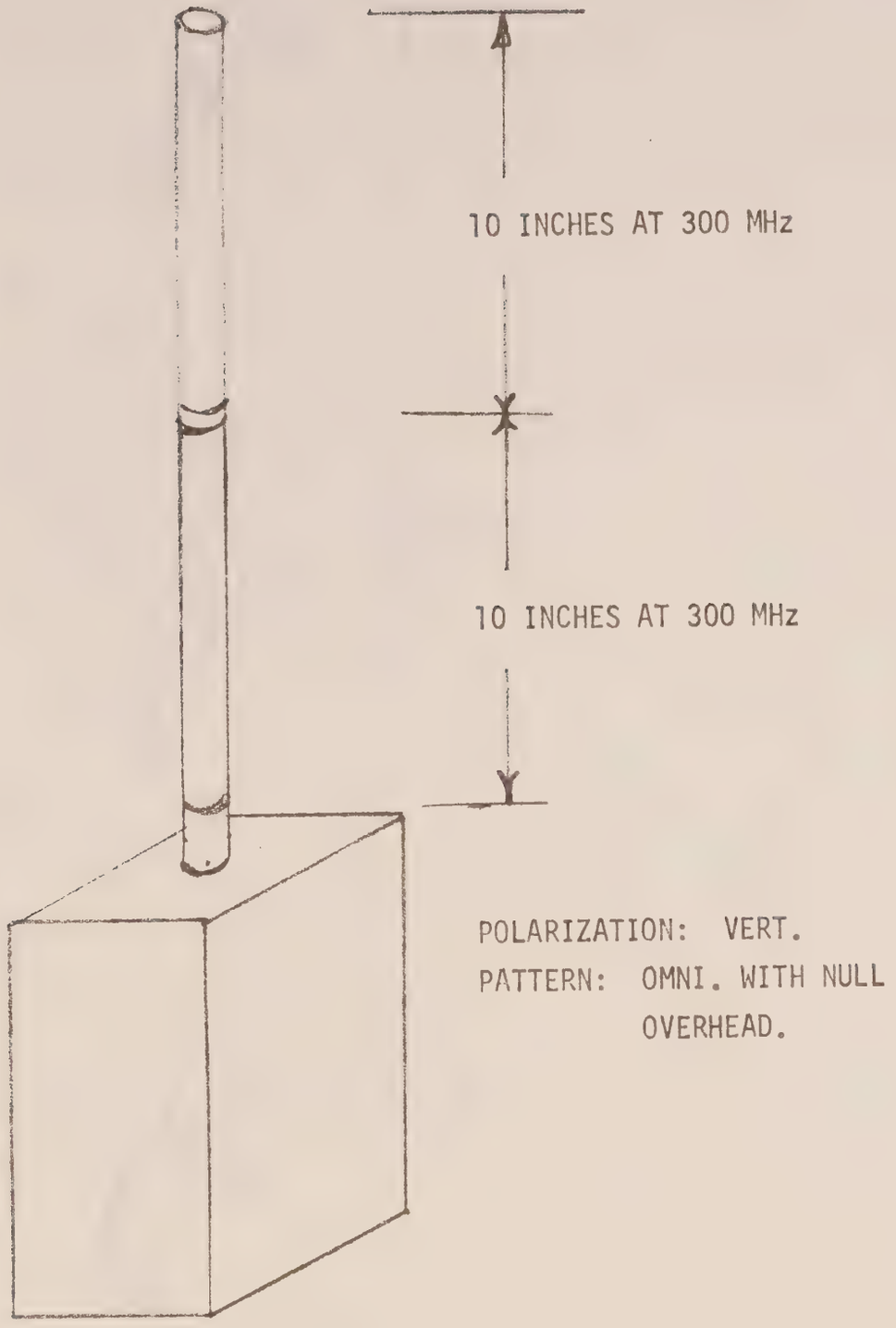



FIGURE 2. HALF-WAVE DIPOLE

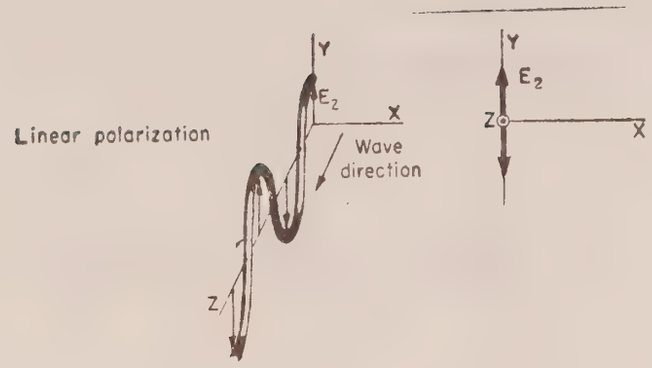



FIGURE 3a.

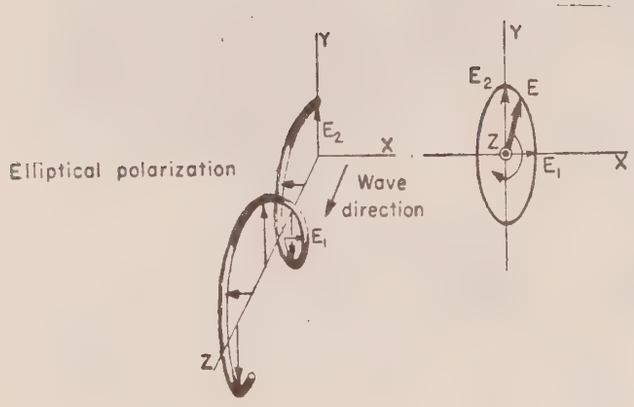



FIGURE 3b.

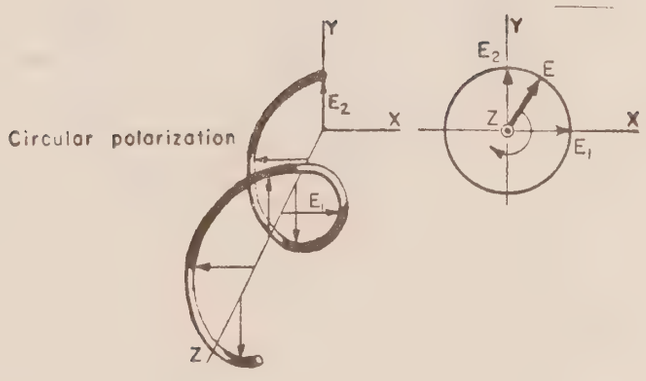



FIGURE 3c.

FIGURE 3. PICTORIAL REPRESENTATION OF LINEAR, ELLIPTICAL AND CIRCULAR POLARIZATION.

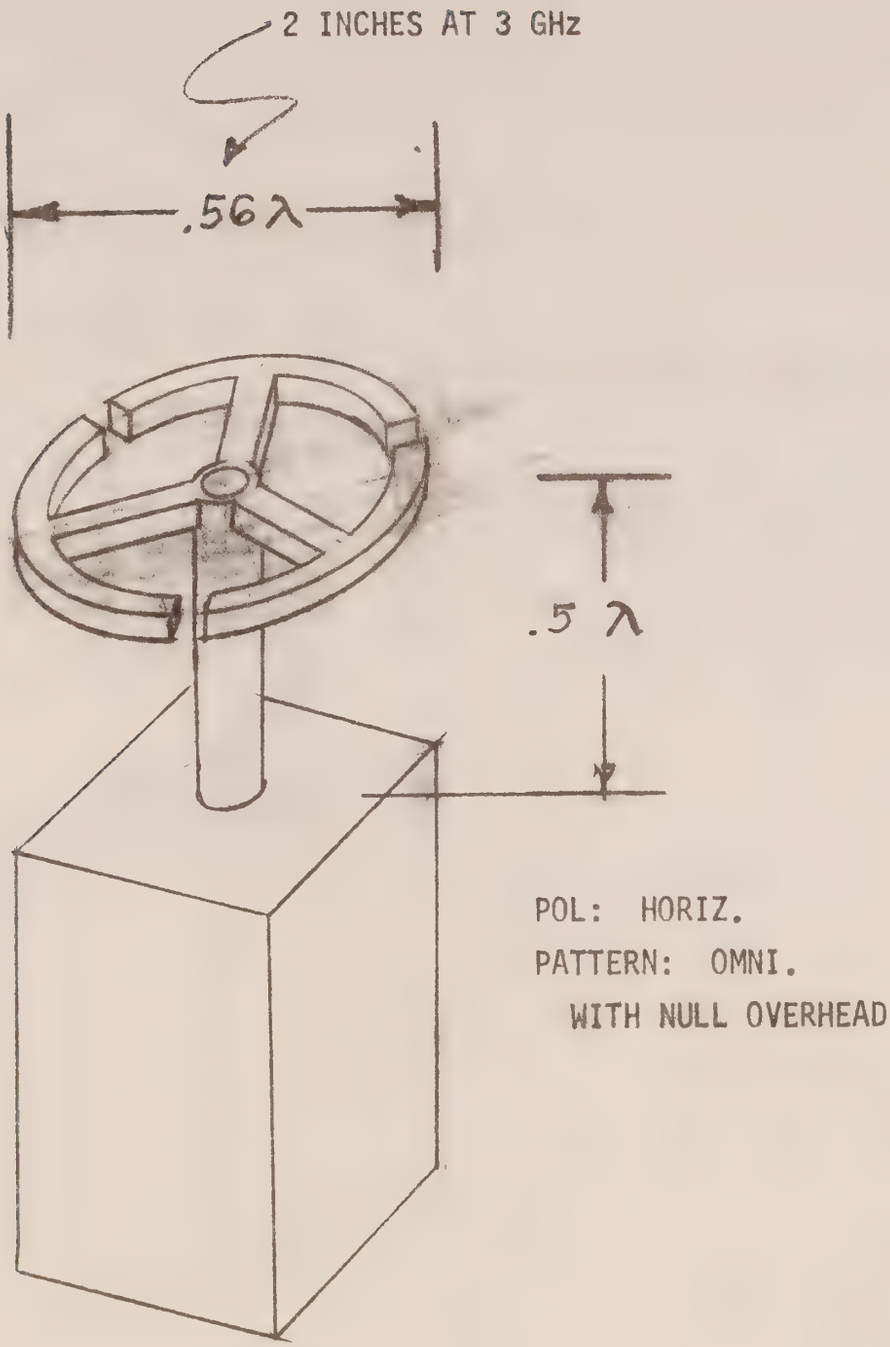
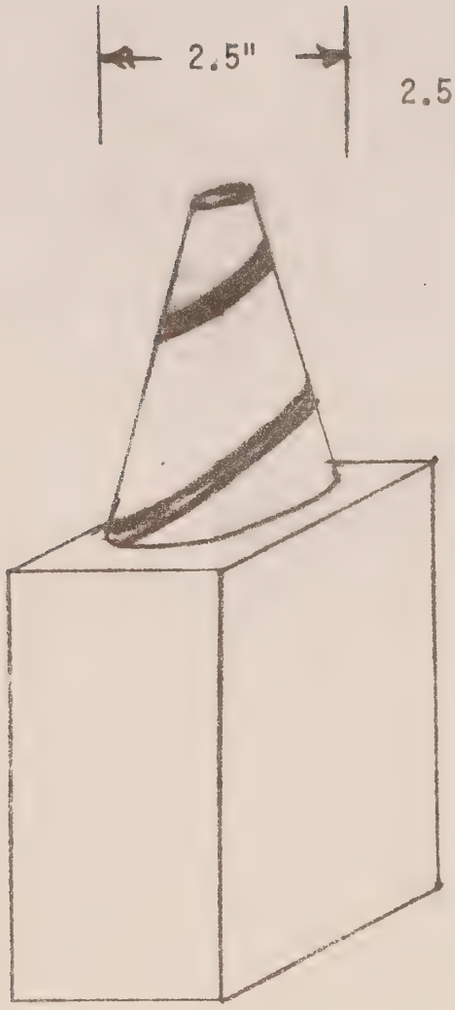



FIGURE 4. TRI-DIPOLE LOOP ANTENNA

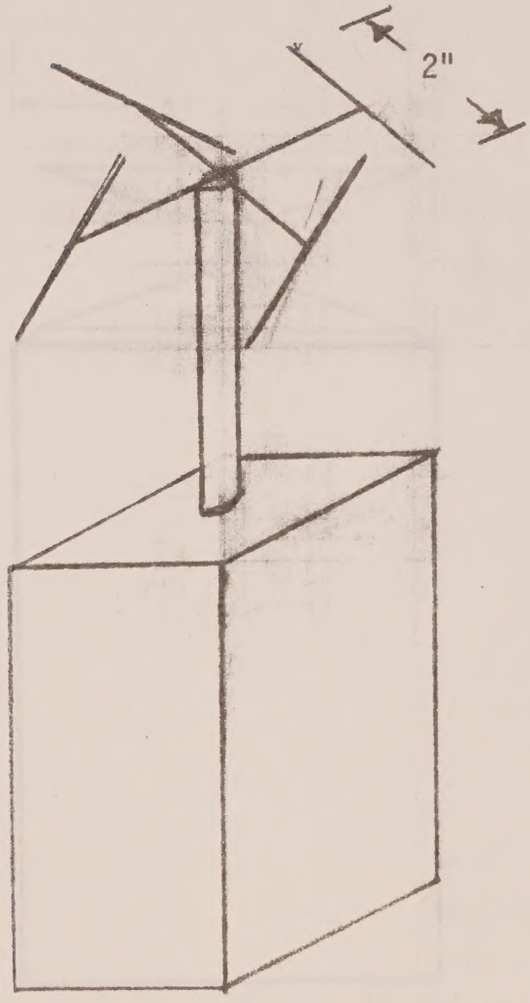



2.5 INCH DIAMETER AT BASE AT 3 GHz

POL: CIRCULAR

PATTERN: OMNI.

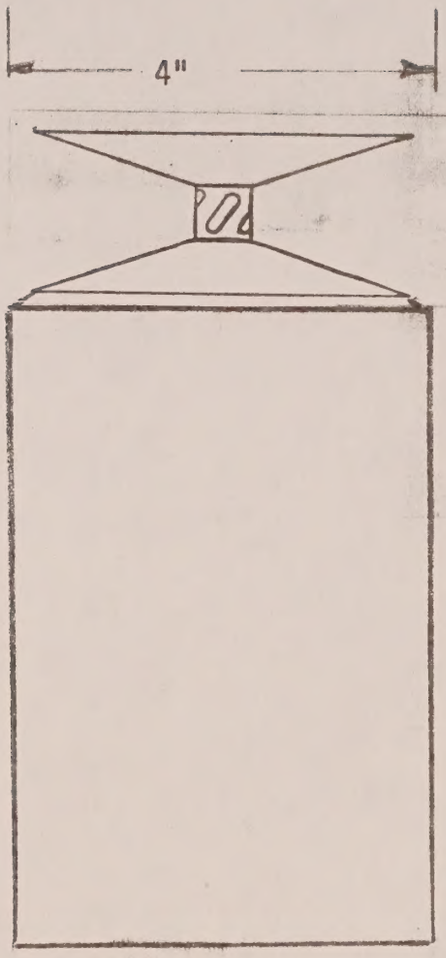
FIGURE 5. CONICAL SPIRAL




DIPOLES ARE ORIENTED AT 45 DEGREES. LENGTH IS 2 INCHES AT 3 GHz.

POL: CIRCULAR
COVERAGE: OMNI

FIGURE 6. DIAGONAL DIPOLES




DIAMETER OF CONE IS
4 INCHES FOR 3 GHz.
POL: CIRCULAR
COVERAGE: OMNI
WITH NULL OVERHEAD

FIGURE 7. SLOT-FED BICONE